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[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

BURNISHING AND DUCTILIZING STEEL.

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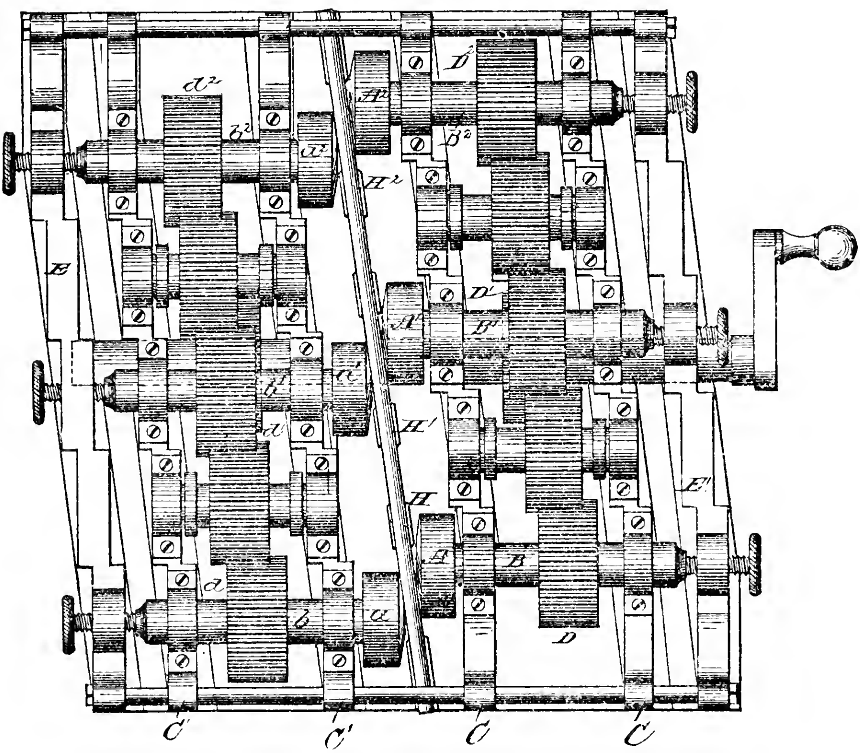
(Read at the Philadelphia Meeting, February, 1881.)

I HAVE discovered a new method by which steel and other metals may be burnished by the automatic action of the burnishing machine, and by which the cost is greatly diminished, and more perfect work produced. And in addition to the polishing and burnishing action of

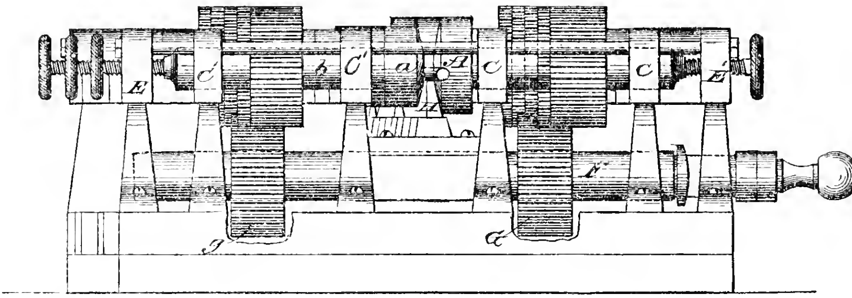
FIG. 1.



the new process, I have discovered that by a certain practice in the process of burnishing, the metal under treatment may be permanently increased in diameter of its cross section, and its ductility in-

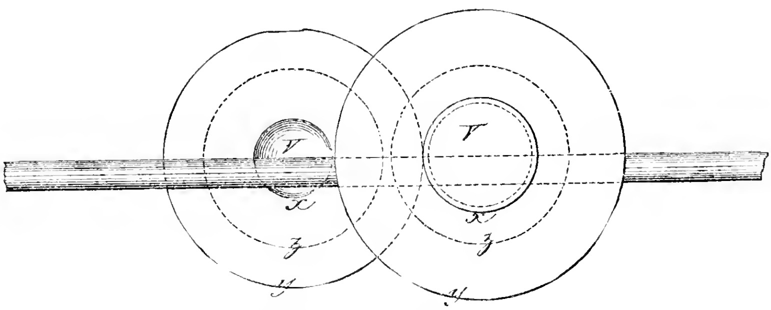
creased from 30 to 90 per cent., at a temperature ranging from 60° to 250° Fahr.

FIG. 2.



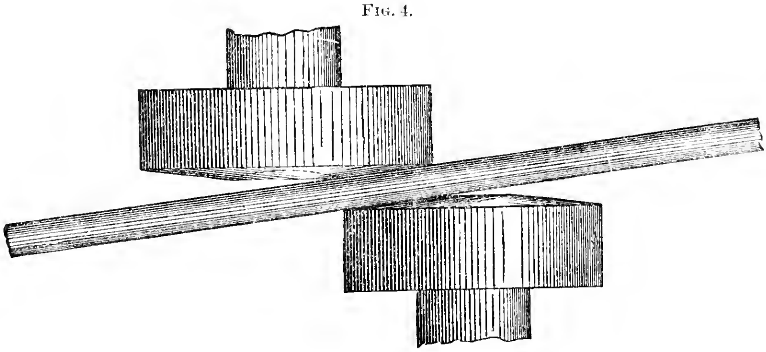
The machine is shown in the accompanying drawings, Fig. 1 is a top view of a continuous disk-machine, Fig. 2 is an end elevation of

FIG. 3.



the same, Fig 3 is a top view of a set of conical disks, and Fig. 4 is a diagram, showing the working-face of one disk and the back of another. Like letters refer to like parts wherever they occur.

FIG. 4.



The series of disks, which in the present instance are six in number, are arranged so that they all operate upon the bar at one

and the same time. The faces of the disks are slightly conical, and the centres of the faces are turned concave, so that the working-face of each disk extends from the edge of the periphery to the outer edge or line of the concave portion of the disk. The disks are of two sizes, the larger being about sixteen inches in diameter and the smaller about fourteen inches. The large disks A A' A^2 are placed upon the same side of the working-line, and the small disks a a' a^2 are placed on the opposite side, the object being to secure a downward bite upon the bar by the large disks and an upward by the small disks, thereby keeping the bar down firmly on to the rests. These disks are mounted on suitable shafts B B' B^2 and b b' b^2, which are set in the standards or housings C and C' in such a manner that the large and small disks are not directly opposite to each other, but bear such relative positions as will bring the outer edge of the working-face of each disk directly opposite to the inner line of the working-face of the adjacent disk. This arrangement is not absolutely necessary, but renders the construction simpler than other modes of arrangement.

The disk-shafts are provided with pinions D D' D^2 and d d' d^2, which mesh into idlers or pinions mounted on shafts, which are set into the standards between each pair of disks. It is necessary to have idlers for the disk-pinions to mesh into, because if they were to mesh into and communicate motion directly to each other every other disk on the same side of the working-line would revolve in an opposite direction, and consequently prevent the mechanism from working.

E E' are end housings, provided with suitable adjusting-screws for the purpose of setting the machine for any given size of work, to adjust the disk-faces in a parallel line and regulate the pressure upon the metal operated upon. F indicates the main driving-shaft, which is provided with pinions G, g, which mesh into the central disk-pinions, D d. H H' H^2 indicate rests, which are set in line beneath and between the disk-faces. These guides or rests are slightly less in width than the diameter of the piece of metal to be operated upon, and for ordinary work they are adjusted to keep the centre of the bar a little below the centre of the disks, that being necessary in order that the resultant action of the forces exerted by the movement of the disks may cause the bar to feed forward as it rotates. The forward speed will depend upon the altitude of the rests in relation to the disk-centres, and if they are adjusted so that the centre of the bar is on the same line as the centre of the disks it

will rotate, but without forward or backward motion. If the rests are adjusted to throw the centre of the bar above the centre of the disks, it will have a backward movement as it rotates.

When power is applied to the main shaft F to rotate the same the pinions G *g* communicate motion to the central disk-pinions D *d*, which turn the idlers, and thus communicate motion to the other disk-pinions, causing all the disks to rotate uniformly. In order to fit these disks for burnishing and ductilizing iron and steel it is necessary that their working-faces should be trued and highly polished, and this I accomplish in the following manner:

The machine having been adjusted for any given size of work and the guides or rests being in a line and adjusted to the proper height, I take a square piece of hard wood of suitable thickness and place it upon a rest in front of the machine. I then oil the disk-faces and sprinkle them with emery, and finally enter the block between the disk-faces, when it will be caught and drawn slowly forward, thus truing and polishing the entire train of working-faces at one and the same time, and also polishing and truing the working-faces of the rests. The machinery is now capable of burnishing and ductilizing the metal when properly adjusted for that purpose, and this adjustment is a matter which will require considerable skill and care upon the part of the operator, as a degree of pressure is necessary in some cases which would be entirely inadmissible in others.

By referring to the drawings it will be readily understood that when the rests are adjusted to any given height the feeding of the bar will be uniform and constant, and therefore the only method of increasing and decreasing the frictional action upon the surface of the metal will be by regulating the pressure as occasion may require. The greater the friction the greater will be the tractive force which tends to draw or film the surface of the metal. The ability of the metal to resist this drawing force depends upon the attraction of cohesion of its particles. This varies in different metals and in the same metals at different temperatures, being greatest at the lowest and least at the highest temperature; and in iron and steel it depends greatly upon the amount of carbon in combination with the metal. Now, it is evident that when the bar is put into the machine its temperature will be gradually raised by the frictional action at each successive pass, and therefore become less and less able to resist the tractive force, and that as its temperature increases the metal will gradually expand in diameter, so that if all the faces are previously adjusted to exactly the same distance apart, not only will

the metal become less able to resist the tractive or drawing force, but the increased temperature of the metals will, by causing such expansion, develop more pressure and frictional tractive force, so that the metal will then be very liable to draw or scab. The disk-faces should therefore be so adjusted as to bring the greatest pressure at the first pass, and to apply a little less at each successive pass until the burnished bar is completed.

In conducting the operation the object is to secure sufficient pressure to compress the inequalities and to develop enough frictional or tractive force to overcome the attraction of cohesion of the particles composing the scale on the surface of the metal, yet not enough to overcome the force of cohesion of the particles which will then form the surface of the metal itself. If the metal has a great force of cohesion and does not possess a tough, tenacious scale, this may be readily effected; but where the conditions are opposite great care must be had and a constant watch kept for signs of filming. Therefore, as it is imperatively necessary that certain degrees only of pressure, frictional action, and tractive force be applied or developed upon the surface of the metal, it is necessary, first, that the metal should have been previously rolled to an exact or uniform gauge, so that when burnishing an undue amount of pressure may not be developed upon its surface at any point; secondly, as the ability of the metal to resist the tractive force is less when at high temperatures, it should be operated upon when in a cold state, or at a temperature not exceeding 500° F.

The machine being in condition, having its working-faces trued and polished, and the metal having been properly prepared by rolling to an exact gauge, a test-bar may be entered and the working-faces gradually tightened up after each pass until a point is reached at which the films begin to show upon its surface. This is an indication that the pressure is too great, and the tightening-screws should be relieved a little and the test-bar again entered, a careful watch being kept for further filming. If none appears the machine is properly adjusted for that sized bar; but if films still continue to form, the pressure must be further decreased until a point is reached at which no films are formed. It is not necessary, however, that the machine should always be adjusted in the manner just described, as burnished bars may be sometimes produced, although a very light pressure is used, as, for instance, where the scale upon the metal is not tenacious and the surface of the metal is very smooth; but in all cases the pressure will be light in comparison with that which is

required for rolling and extremely light when compared with that required for cold-rolling. I am unable to give the required degree which will be necessary in all cases, as I find that the pressure varies upon any given point, according to the difference in the diameters of the bars operated upon, the larger diameters burnishing under heavier pressure than the smaller; and, moreover, the pressure upon any given point may vary accordingly as the width of the burnishing-faces used varies. The wider the disk-faces the greater will be the amount of frictional action and tractive force upon any given part of the bar in any given time, and consequently the less must be the pressure. The converse of the proposition is also true, viz., the narrower the disk-faces the less the frictional action and the greater the pressure admissible; but the working-faces must never be made very narrow, as in such case so great a pressure would be required to develop the frictional action which is necessary that the operation would be entirely changed, and cause a reduction of the metal and displacement of its particles, as in rolling. Finally, I find that the pressure may vary with the different temperatures and natures of the metal operated upon. Therefore, no precise rule can be adhered to for all cases, except, first, to have all stock previously rolled to a uniform gauge; secondly, to have all the burnishing-faces turned perfectly true with a high polish; thirdly, to have the burnishing-faces constructed of sufficient width to develop a sufficient amount of frictional action when a light pressure is applied. Then feed the bar at a proper temperature, and apply the pressure from an exceedingly light one to the highest the metal will stand without filming.

The machine being in the condition specified and adjusted as specified, rough bars of metal in a cold state are inserted, one at a time, between the receiving-disks. They are caught, rotated rapidly, and drawn forward, travelling forward with a speed of from one to sixty feet per minute, according to the size of the bar, height of the rests, and speed at which the disks rotate, and are delivered perfectly straight, of a true cylindrical form and highly burnished. In some cases, however, when the bars are of a large diameter, and are covered with a tough, tenacious scale, additional passes may be required to accomplish this result.

When burnishing cold metallic bars I prefer to place narrow pans, containing petroleum or other oil, beneath the second and third pair of disks. These pans are of sufficient size to contain the required quantity of oil, and are shaped so as to form a sheath or trough, in which the lower portions of the disks revolve. The effect

of the application of the oil is to prevent the working-faces of the disks from scratching and marring, and it also has a certain effect upon the finished product, of which I shall speak hereafter.

When it is designed to straighten and burnish metal directly as it comes from the rolls during its manufacture, the process should be the same as before specified, except that the metal should be allowed to cool to a dark red heat, and a considerable quantity of water should be let upon the first set of disks and upon the bar, to reduce the temperature of the metal to the proper degree, so that in its rapid contraction the scale will be loosened. A steam or air blast should be used to carry the scale away, and the first and second set of disks will then readily remove any portion of scale which may still adhere to the bar. The metal will then pass from the first to the second set of disks, thoroughly cleaned and partially burnished, and the second and third pair of disks will, by the frictional action, which also burnishes, heat the surface of the bar. Consequently, the lighter components of the oil will be vaporized, leaving the bar coated with carbonaceous matter, which is apparently forced into the pores of the metal by the action of the disks, and the bar, when burnished, is found to have a much finer appearance than if it had been burnished without the oil, and it is also enabled to resist oxidation to a greater degree.

For the purpose of illustrating the frictional action which may be obtained by the employment of disk-rolls, I will again refer to the drawings, in which Fig. 3 represents a top view, and Fig. 4 is a diagram, of a set of disk-rolls, the latter showing the back of a sixteen-inch and the working-face of a fourteen-inch disk. V indicates the concave portion of the disk-faces, which is five inches in diameter in the fourteen and seven inches in diameter in the sixteen-inch disk. x indicates the inner lines or edges of the working-faces; z the neutral lines, or those portions of the disks at which their rate of speed when working is equal to the surface speed of the bar in rotating; and y the outer edges or lines of the working-faces of the disks at their peripheries. It is well understood that the different portions of the disk-faces travel at different rates of surface speed, according to their position with relation to the disk-centres.

When a cylindrical bar is fed into the disks it will rotate, and, all portions of the surface of the bar being at the same distance from the axis or centre, will travel at the same surface rate of speed, and as the working-faces of the disks travel, having differential rates of

surface speed, as before stated, great frictional action is produced on the working-surface of the disks and the surface of the bar; or, in other words, this result follows because the surface speed of the bar and disk-faces is the same only on the theoretical or neutral lines indicated by the letter *z*, the disk-faces travelling at a gradually increasing speed from the neutral line to the peripheries, and at a gradually decreasing speed from the neutral line to the inner lines of the working-faces of the disks. If, therefore, as in ordinary practice, the working-faces of the disks are four inches in width from the outer to the inner edges of the working-faces, the area of the small disk will be $113\frac{96}{1000}$ square inches, and that of the large disk $138\frac{220}{1000}$ square inches, thus making a total area of $251\frac{316}{1000}$ square inches of frictional surface which slips or rubs over the surface of the bar at each revolution of the disks.

In addition to the frictional action of the disk there is that of the rests. A bar one and one-eighth inch in diameter will rotate (the rests being at the proper height) eight times to each revolution of the disks and feed forward about two inches to each revolution of the disks, or one-quarter of an inch to each revolution around its own axis. The length of the rest's working-surface is usually about five inches, so that the bar will revolve twenty times over the polished surface of the rest during the time any given portion of it passes from one end to another of the rest, and the rest acts the same as if the bar were rotated in a lathe and a burnishing-tool pressed against it with the same degree of force during twenty revolutions around its axis. Finally, there is the frictional action which arises from the forward movement of the bar over the burnishing disks and rests.

One of the effects produced by the frictional action to which I have referred, or by the action of the heat developed by the friction, is to gradually expand the metal during the burnishing operation, so that as the bar travels forward the pressure will become augmented, unless the tightening-screws are adjusted lighter for the latter passes; and I have found that, when they are properly adjusted, the metal will in some cases retain permanently its increased diameter, which I have found in all cases to indicate a slightly decreased tensile strength, elastic limit, and a greatly increased ductility in the metal. When, however, the tightening-screws were adjusted so as to compel the bar to retain its original diameter, I have found the elastic limit and ductility are the same as in the

original state, and that the tensile strength remains almost the same as in the original state previous to the operation.

The following record of tests made by tension shows clearly the changes which are effected in the physical nature of the metal by the process:

Marks and Condition of Pieces.	Original Diameter.	Diameter after Fracture.	Original Cross-Section.	Cross-Section after Fracture.	Elastic Limit.	Elastic Limit per Square Inch.	Tensile Strength.	Tensile Strength per Sq. Inch Original Section.	Elongation in Five Inches.	Elongation.
	In.	In.	Sq. In.	Sq. In.	Pounds.	Pounds.	Pounds.	Pounds.	In.	Per Cent.
459 Rough, ...	1.013	.955	.806	.716	51,000	63,283	88,235	109,486	.547	10 94
460 Bright, ...	1.014	.853	.807	.571	47,500	58,823	86,795	107,486	.953	19.06
461 Bright, ...	1.016	.851	.811	.569	49,500	61,058	88,395	109,035	.797	15.94
462 Bright, ...	1.012	.969	.804	.737	48,000	59,674	88,305	109,782	.500	10.00
463 Bright, ...	1.015	.910	.809	.650	47,500	58,704	87,365	107,972	.656	13.12
464 Rough, ...	1.012	.952	.804	.712	48,000	59,674	87,500	108,782	.500	10.00

Nos. 459, 460, and 461 were cut from the same bar of steel. No. 459 was cut from the rough end, which was in the same condition as it came from the rolling-mill. Nos. 460 and 461 were bright, and were cut from the end that had been burnished. No. 459 broke just above the top centre punch-mark. No. 460 broke between the points of measurement. No. 461 broke at the top centre punch-mark.

Nos. 462, 463, and 464 were cut from one bar of steel, each end of which had been burnished. No. 464 was cut from the middle of the bar, which was rough as it came from the rolling-mill. No. 462 was cut from one end, and No. 463 from the other end, both of which had been burnished. No. 462 broke one and one-half inch above the top centre punch-mark. No. 463 broke one-half inch below the top centre punch-mark. No. 464 broke one inch above the top

centre punch-mark. No. 462 did not break at its smallest diameter, which was midway between the points of measurements.

All the changes or phenomena which present themselves in the finished product show that the operation to which it has been subjected embodies some principle which has never before shown its effects in the product of any rolling, hammering, or compressing operation, nor in the product of any burnishing, brightening, or polishing operation known heretofore to the art of metallurgy. For instance, that indicated by the permanent increase in the diameter of the metal, although at the time it is confined between parallel surfaces and under-pressure, the operation being conducted so that the heat developed does not generally exceed 250° Fahrenheit, which would not be sufficient, no matter how long continued, to anneal or ductilize heavy cold bars of steel by any known process.

When steel is required for structural purposes it must be able to resist concussion sudden shocks, rapid vibration, and deflection, and give due warning, before final rupture takes place, by elongating within certain degrees. Consequently, heretofore, the steel has been made low in carbon to secure the required ductility, and therefore possessed a low tensile strength. This steel is annealed after its manufacture, to bring it back to its normal condition, and destroy in a measure the effects produced in its physical structure by the ordinary rolling operation, since all rolling, hammering, and drawing leave the physical structure of the metal in an abnormal condition, producing hardness, brittleness, and liability to rupture from concussion, vibration, or rapid deflection.

Annealing steel reduces its ability to resist tensile, compressive, and torsional strain, as well as its elastic limit, and increases its elongation or ductility. It is a slow operation, lasting generally from five to twenty-four hours, and leaves the metal covered with scale. By my process the ductility of the metal may be greatly increased without the formation of a scale upon its surface, and in a very rapid manner. In comparing it with ordinary annealing operations the following facts become apparent:

First. As the metal is previously rolled to an exact size, and the disk-faces are adjusted to exert exactly the same degree of pressure and frictional action upon all parts of the bar, the ductility of the metal should be constant and uniform at all points, whereas in annealing the temperature of the furnace varies at different parts, consequently the metal cannot be uniformly annealed.

Second. As the bars are all of the same size previous to the burnishing operations, the same degree of ductilizing action should be had upon each, and consequently they should all be regularly ductilized, whereas in annealing the process is not automatic, and the bars are charged and drawn by hand, so that they are exposed to heat for irregular periods of time.

Third. The ductilizing effect is produced by this process at a heat never exceeding 500° Fahrenheit, and this is too low to deprive the bar of carbon; or, if it does so to any extent, it does it uniformly, whereas in annealing the bar loses considerable carbon, and loses it unequally, so that not only is the tensile strength reduced considerably, but it varies at different points of the bar.

Fourth. As the ductilizing of the metal is constant and uniform, its internal strains should be regularly and uniformly relieved, whereas in annealing the temperature always varies in different parts of the bar; hence its internal strains should be irregularly relieved.

Fifth. As the temperature in this process is very low and uniform upon all parts of the bar it remains perfectly straight in cooling, whereas in annealing the high and uneven temperature of the metal causes it to warp and become distorted in cooling.

Sixth. By my process I am enabled to ductilize metal at the rate of one foot per second to one foot per minute, whereas annealing operations require several hours or days for their completion.

This process will be found to be peculiarly adapted to the production of steel shafting, piston-rods, and also for very light work, such as burnished steel for pivots for watches and clocks, etc., in which latter case it is evident that the mechanism employed must be of a reduced size suitable for the work to be accomplished.

Comparing the mechanical effect of this process, with other well-known processes, the difference is very marked. Wrought iron possessing a tensile strength of 50,000 pounds per square inch, and an elastic limit of 30,000 pounds per square inch, and exhibiting an elongation of 25 per cent., will, when cold-rolled by the Lauth process, possess a tensile strength of 68,600 pounds, and an elastic limit of 59,600 pounds, but the ductility is reduced to an elongation of 6 per cent. When such cold-rolled iron is annealed it is found to possess a tensile strength of 48,700 pounds, an elastic limit of 32,000, and an elongation of 15 per cent.

Professor R. H. Thurston, in his paper on " Mechanical Treatment

of Metals,"* said: "All known and actually practiced methods of so altering the character of the metals used by the engineer, involve, directly or indirectly, the elevation of the original elastic limit of the material." In this process, however, the elastic limit is slightly reduced.

In conclusion I would add, that the phenomena exhibited in this process are not explicable by any of the laws of molecular physics known to me.

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* Metallurgical Review, vol. i, page 1.